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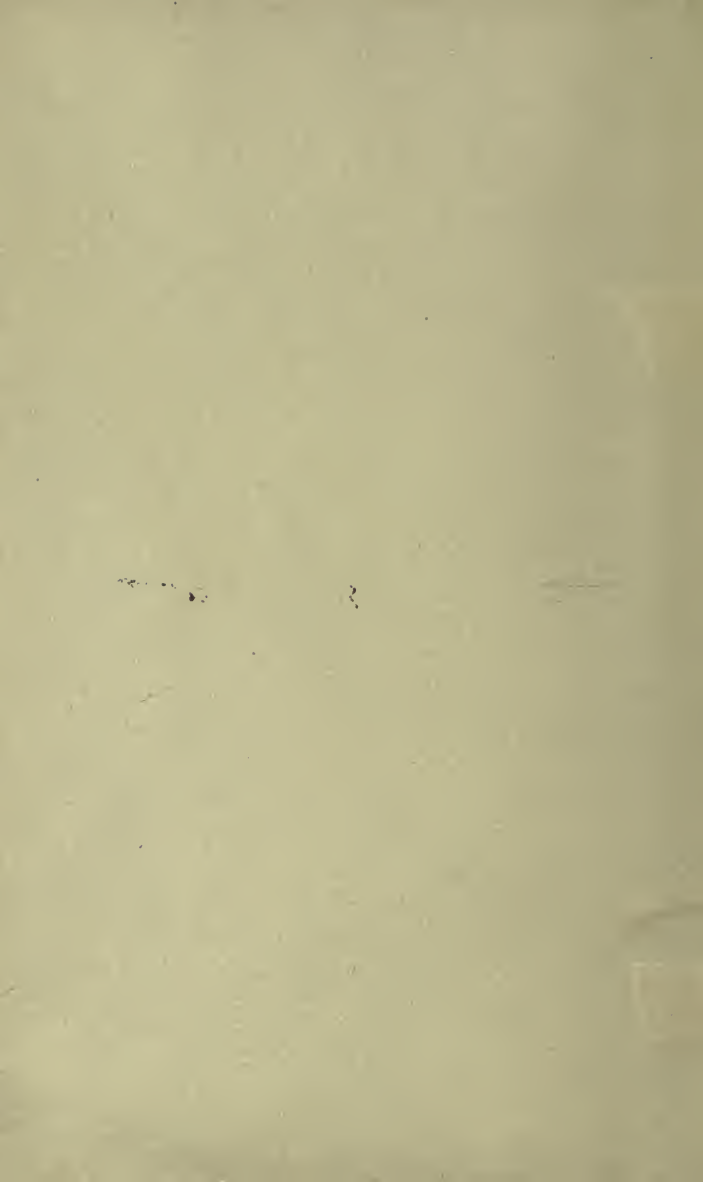
FIRST STAGE

BY

F. P. ARMUTAGE, M.A.

CHIEF SCIENCE MASTER AT ST. PAUL'S SCHOOL
AUTHOR OF 'A HISTORY OF CHEMISTRY'

LONGMANS, GREEN, AND CO.
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CHEMISTRY, FIRST STAGE

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A HISTORY OF CHEMISTRY

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CHEMISTRY, SECOND STAGE

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F. P. ARMITAGE, M.A.

CHIEF MASTER ON THE SCIENCE SIDE AT ST. PAUL'S SCHOOL

(SECOND AND ENLARGED EDITION)

LONGMANS, GREEN, AND CO.

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PREFACE

TO

THE SECOND EDITION

FURTHER experience tells me that it is convenient if demonstrations are given to whole classes at once rather than to single pupils or small groups. It is essential however that pupils, in advance of their fellows, do not proceed with their work till they are in possession of the facts conveyed by the demonstrations, and have answered the questions which follow. In this new edition the endeavour has been made, by photography and letterpress, to reconcile the convenience of the demonstrator with the needs of all his pupils.

Three sets of questions are added, from which choice can be made when it is desirable to test a pupil's mastery of this first stage of laboratory training and the learning that should supplement it. The pages devoted to derivations of words used to signify various substances and phenomena are likewise new to this book.

vi PREFACE TO THE SECOND EDITION

It is the attitude of mind of the investigator that we would encourage in our pupils, and it has seemed good to bring them into touch with the work of Black. Black's words are lucid and his reasoning comprehensible even to the young, his experiments, moreover, are easily repeated.

I would express obligation to several past and present colleagues, Messrs. G. C. Fennimore, H. T. L. Lees, G. H. Woollett, E. T. Lancaster, and C. N. Langham, for hints and valuable criticism; to Mr. Langham again for the photographs; and to a former pupil, Mr. J. D. M. Harvey, for the diagrams and drawings.

F. P. A.

LONDON,
August 5, 1917.

PREFACE

TO

THE FIRST EDITION

I HAVE tried many methods of teaching Chemistry in its earliest stages and have found none so satisfactory as that suggested in the following pages. The notes on various substances and phenomena will help to satisfy a pupil's curiosity and interest, and will supply him with information for the answering of questions that occur to the teacher. But it is the manner rather than the matter of Chemistry that has educative value.

To treat the subject satisfactorily the class teacher should relegate training in laboratory handicraft to an assistant : his own time is most profitably spent in general direction and supervision, in examining note-books, asking questions, and correcting answers.

F. P. A.

LONDON,
August 10, 1915.

CONTENTS

	PAGE
GENERAL INSTRUCTIONS	1

RECOGNITION OF CHEMICAL CHANGE

EXPERIMENTS 1-6. THE EFFECT OF HEAT ON SUNDRY MINERALS	4
„ 7-9. SUBSTANCES COMMON TO DIFFERENT MINERALS	6
DEMONSTRATION.—SOME CONSTITUENT PARTS OF AIR	8

ACIDS, BASES, AND SALTS

EXPERIMENTS 10-15. SULPHURIC ACID : ITS ACTION ON METALS AND THEIR OXIDES	10
DEMONSTRATION.—HYDROGEN AND ITS PROPERTIES .	13
EXPERIMENTS 16-19. HYDROCHLORIC AND NITRIC ACIDS : CHLORIDES AND NITRATES	15
DEMONSTRATION.—PREPARATION OF HYDROCHLORIC AND NITRIC ACIDS	16
EXPERIMENT 20. PREPARATION OF OXYGEN	20
DEMONSTRATION.—THE PROPERTIES OF OXYGEN .	21
DEMONSTRATION WITH EXPERIMENTS 21-22. TREATMENT OF CORK AND GLASS TUBING	23

ALKALIS

EXPERIMENTS 23-25. AMMONIA AND ITS PROPERTIES	25
„ 26-32. QUICKLIME AND OTHER ALKALINE SUBSTANCES	28

	PAGE
DEMONSTRATION.—PREPARATION AND PROPERTIES OF QUICKLIME	29
EXPERIMENT 33. COMBINATION OF AN ALKALI WITH OXIDE OF SULPHUR	35
EXAMINATION PAPERS	39
NOTES	44
EXTRACTS FROM A PAPER BY JOSEPH BLACK (1755) .	75
SOME DERIVATIONS	79

CHEMISTRY

FIRST STAGE

GENERAL INSTRUCTIONS

THE pupil must have a rough note-book and a fair note-book. All notes, drawings of apparatus, and answers to questions must be corrected and then copied into the fair note-book, and they must be copied in consecutively.

The work must be done in the order given—experiments must not be begun till all preceding questions are answered.

Careful observations must be made and recorded, it may be as to—

- (a) The appearance of the substances used.
- (b) Changes of colour and physical state during and after heating.
- (c) Signs of gas being evolved.
- (d) The production of water vapour and fumes.

The record must have the following form :

Experiment	Result
<i>Here state what the experiment is, thus :</i> (1) Iron pyrites is heated in a crucible. (2)	<i>Here state what you observe, thus :</i> (a) The colour of the pyrites changes from yellowish to black. (b) A pungent smell, like the smell of burning sulphur, is very noticeable. (c) A blue flame plays over the surface of the powder. (d) A powder is left which is black when hot, but dull red when cold.

Answers to questions in every case must suggest the nature of the question. A suitable answer to the question, 'If any one substance

is present in the three minerals iron pyrites, copper pyrites, and blende, what is that substance? ' would be :

The one substance common to the four minerals iron pyrites, copper pyrites, blende, and sulphur is sulphur, for not only do the first two give a sublimate of sulphur when heated in test-tubes, but all give the same smell when heated in crucibles exposed to the air.

It is very important that small quantities are used—unless directions to the contrary are given—and that the experiment is continued until no further change occurs. The larger the quantity used, the longer it is before a change is complete.

Substances obtained in the course of laboratory work must be preserved in labelled sample tubes. Many of them will be required for further examination.

Drawings must show a medial section of the apparatus, and the relative sizes of flasks, test-tubes, burner, &c., must be kept in mind.

Demonstrations are made to the class as a whole ; those in advance of the others will draw the apparatus photographed, in section, and will study carefully the account of the experiment appended.

RECOGNITION OF CHEMICAL CHANGE

The effect of Heat on Sundry Minerals

Experiment 1.—Heat as much sulphur as will cover a threepenny-piece, in a crucible.

Experiment 2.—Slowly heat some sulphur—half a teaspoonful—in a test-tube, till vapour issues from the mouth.

Experiment 3.—Grind the minerals iron pyrites, copper pyrites, and blende—half a teaspoonful of each—to fine powder and heat them, gently at first, then strongly, in small open crucibles. Stir the powders from time to time and blow on their surface with the mouth. If possible the three should be heated at the same time, and the operations should be continued till no further obvious change occurs.

Experiment 4.—Heat portions of the same three minerals successively in test-tubes.

Questions :

1. What is the meaning of the word 'mineral' ?
2. What is there in common in the behaviour

of the four given minerals, (a) when heated in crucibles, (b) when heated in test-tubes ?

3. If any one substance is present in all the minerals, what is that substance ?

4. How may the blue flame playing over the surface of some of the heated minerals be explained ?

5. How do you account for the difference in behaviour of these minerals when heated in crucibles and when heated in test-tubes ?

6. How do you explain the effect of blowing with the mouth on the heated powders ?

Experiment 5.—Heat siderite, malachite, and calamine respectively, (a) in crucibles, (b) in test-tubes.

Experiment 6.—Heat as much charcoal as will cover a threepenny-piece, (a) in an open crucible, (b) in a test-tube.

Questions :

1. Is there any difference in the effect of heating siderite, malachite, and calamine in crucibles and in test-tubes ?—or

2. In the effect of heating charcoal similarly ?

3. What evidence have you that a gas is

given off from the heated malachite and calamine ?

4. Do the powders left suggest any kinship with those left after heating iron pyrites, copper pyrites, and blende in crucibles ?

5. What do you think is the cause of the disappearance of sulphur and charcoal when they are heated in open crucibles ?

Substances Common to different Minerals

Experiment 7.—Mix half the black powder obtained by heating malachite, with one quarter its bulk of very finely powdered charcoal, and heat the mixture strongly for ten minutes in a covered crucible placed in a Davies' crucible furnace. When the crucible is *cold*, pour its contents on paper and examine them carefully.

Experiment 8.—(A) Mix the remainder of the black powder obtained from malachite with twice its bulk of very finely powdered charcoal, and heat as in Experiment 7. When the contents of the crucible are cold, pour them into a beaker and allow water from the tap to play on them gently till the charcoal that remains is washed away.

(B) Perform the same experiment with the powder obtained by roasting copper pyrites.

Experiment 9.—(A) Treat the powder obtained by heating siderite as in the first part of Experiment 8. When the crucible is cold, pour its contents on to paper and draw a magnet through them. Remove any adhering particles from the magnet and repeat the process till separation of the parts of the powder is complete.

(B) Perform the same experiment with the powder obtained by roasting iron pyrites.

Questions :

1. How do you account for the different effects on the charcoal noticed in Experiments 7 and 8 ?

2. What is the heavy powder left after washing in Experiment 8 ?

3. Define the terms ' Density ' and ' Specific Gravity.' Explain the action of water as a separator in Experiment 8.

4. What is the black powder separated by the magnet in Experiment 9 ?

5. What is it that, through the agency of charcoal, has been removed from the black powder and the reddish powder used in Experiments 8 and 9 respectively ?

6. What evidence have you that the black powders obtained from malachite and copper pyrites and the reddish powders obtained from siderite and iron pyrites contain the same substances respectively ?

Some Constituent Parts of Air

Demonstration.

Air is passed slowly over finely divided copper heated in a combustion tube, and the gas that issues is collected over water and tested with a lighted taper.



The large glass vessel is connected with a water supply by rubber tubing, and the water that passes into it drives air over copper heated in the combustion tube. Such air as does not combine with the copper is collected over water. The copper, where the air

enters the tube, goes black ; where the air leaves the tube, it remains bright. The air collected is therefore quite different from ordinary air. When the collecting jar is full of gas, a glass plate is passed under its mouth. The collecting jar with its contents is removed from the water and set upright. The glass

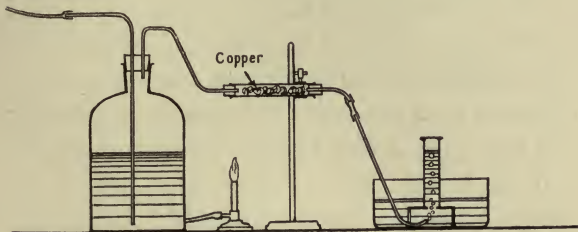


plate is removed and a lighted taper is immersed in the gas. The taper is extinguished at once.

And so there is something in the air which combines with copper to form a black substance, and something else which does not combine with copper, which moreover does not support the flame of a burning taper.

Questions :

1. Why is it that whereas the copper in the above demonstration turns black near the point of entrance of air, it remains unchanged in the farther part of the tube ?

2. Why must the copper used be finely divided ?

3. Would sulphur or charcoal fulfil the same purpose as the copper ?

4. Why is it that the gas that is collected will not support the combustion of a taper ?

5. If that part of the air which is separated by the copper is called oxygen, what names would you suggest for the black and reddish powders obtained from malachite and siderite respectively and for the products of the combustion of sulphur and charcoal ?

6. Define the terms 'element,' 'compound,' 'mixture.'

7. What reasons have you for regarding copper as an element, iron pyrites as a compound, air as a mixture ?

8. What do you mean by oxidation ?

ACIDS, BASES, AND SALTS

Sulphuric Acid : its Action on Metals and their Oxides

Experiment 10.—(A) Grind crystals of green, blue, and white vitriol to fine powder, and heat as much of each as will cover a threepenny-piece

in crucibles in a crucible furnace till no further change takes place. Meanwhile

(B) Heat some more crystals of the same substances in test-tubes.

Experiment 11.—Repeat Experiment 9 with some of the powder obtained from green vitriol in Experiment 10 (A).

Experiment 12.—Place half a teaspoonful of powdered green vitriol in a combustion test-tube and insert the mouth of this tube into the mouth of a boiling-tube. Cover the end of the boiling-tube with filter paper moistened with cold water. Set up the apparatus on a retort-stand—the test-tube must be horizontal—and heat the green vitriol as strongly as possible. Liquid will condense in the boiling-tube, and the white fumes that are evolved later will dissolve in this liquid. Continue heating for half an hour.

Demonstration.—Folding filter papers, fitting them to a funnel, and reducing their size.

Experiment 13.—(A) Put one drop of the liquid obtained in the last experiment on a piece of blue litmus paper.

(B) Dilute the liquid that remains to twice

its bulk, with water. To half of it, after warming, add the powder obtained by heating blue vitriol, in Experiment 10 (A), bit by bit, till no more dissolves; to the other half (also warmed) add iron, obtained in Experiment 9, till there is no further effervescence. Filter the liquids on to watch-glasses, using a minute filter paper, and leave them in a desiccator till crystals separate.

Questions :

1. What reason have you for supposing that green, blue, and white vitriol have much in common?

2. What elements do you think are common to green, blue, and white vitriol?

3. What names would you give to the powders that are left in the crucibles after heating these three substances, and why?

4. What names would you give to the crystals that are formed in Experiment 13 (B).

5. Define the terms 'acid,' 'base,' 'salt.'

6. Under what circumstances are blue and green vitriol found in nature? Explain their occurrence.

7. What name would you suggest for the liquid obtained by heating green vitriol?

Experiment 14.—Half-fill a small evaporating basin with dilute sulphuric acid, warm it and pour in copper oxide bit by bit till no more dissolves. Filter the solution and cool. Pour off the supernatant liquid—the mother liquor—and dry the crystals of blue vitriol or copper sulphate between folds of filter paper.

Experiment 15.—Repeat Experiment 14, using (a) iron filings, (b) zinc oxide, (c) zinc, instead of copper oxide.

Hydrogen and its Properties

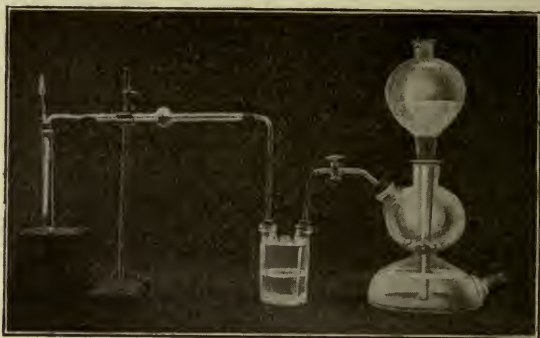
Demonstration.—(A) The preparation of hydrogen by the action of zinc on dilute sulphuric acid.

(B) The action of hydrogen on copper oxide.

(C) The combustion of hydrogen in air.

A Kipp's apparatus is charged with zinc and dilute sulphuric acid. When the tap is turned on hydrogen escapes and acid enters the middle compartment and acts on the zinc. If the tap is turned off, the hydrogen drives the acid again into the bottom compartment and no more gas is evolved. The hydrogen passes through a Woulfe's bottle containing concentrated sulphuric acid—such acid combines very readily with water—and is thereby made quite dry. The copper oxide, when gently heated in the stream of hydrogen,

is reduced to metallic copper, so much heat being given out that the powder becomes red hot. A liquid collects in the test-tube which has the appearance and taste of water. The hydrogen is lit as it issues from the test-tube and a cold plate is held over the almost colourless flame; small drops are deposited on the



plate, which also have the appearance and taste of water.

Hydrogen then combines with something present in copper oxide and thereby forms water; this something is present in the air, for hydrogen burning in air also forms water: and the heat produced by the combination is sufficient to make the copper red hot and the hydrogen luminous.

Questions :

1. What difference do you notice in the action of sulphuric acid on the oxides of copper

and zinc and on the metals iron and zinc respectively ?

2. What are the crystals formed (a) by solution of zinc, (b) by solution of zinc oxide in dilute sulphuric acid ?

3. How do you account for the difference in the action of sulphuric acid on zinc and zinc oxide ?

4. What is meant by the terms 'metal,' 'non-metal,' and 'oxide' ?

*Hydrochloric and Nitric Acids : Chlorides
and Nitrates*

Experiment 16.—Place a few crystals of (a) rock salt, (b) nitre, (c) sal-ammoniac in three test-tubes respectively and *just* moisten them with concentrated sulphuric acid. Notice what happens (a) before heating, (b) after heating, and test any gas or vapour that may be evolved with blue litmus paper.

Questions :

1. What is produced other than salts by the action of sulphuric acid on copper oxide and zinc oxide ?

2. What would you expect to be the action of hydrogen on heated ferric and zinc oxides ?

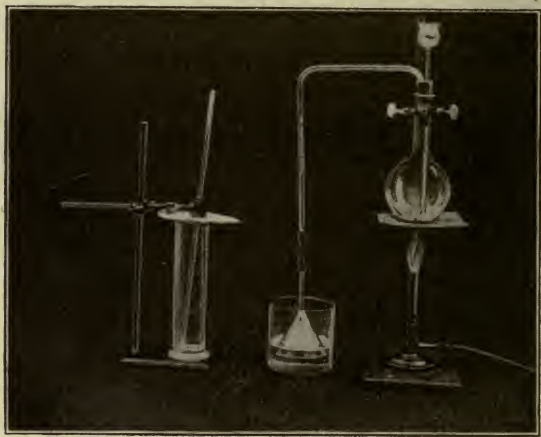
3. What is water made of? Is it a compound or a mixture?

4. What do you mean by reduction?

5. What precautions are to be taken in using concentrated sulphuric acid, and why?

[*Preparation of Hydrochloric and Nitric Acids*

Demonstration.—(A) Hydrochloric acid; its solubility in water.



(B) The method of obtaining a solution of the gas.

(C) Nitric acid.

(A) Rock salt is placed in a flask and concentrated sulphuric acid is poured on to it through the thistle funnel. When the evolution of gas slackens, the flask is gently heated. The hydrochloric acid being heavier than air passes to the bottom of the gas collecting jar—shown on the left of the photograph—and displaces the air. This method of collecting a gas



is the method of *upward displacement*. The filter paper that covers the jar prevents in some measure the re-entrance of air, and prevents too the loss of hydrochloric acid while the jar is being inverted over water. When this is done, the water, coloured blue with litmus, almost fills the jar and becomes red.

(B) To make a solution of hydrochloric acid the funnel is used as shown. Owing to the great solubility of the gas there is a tendency for the water to

be pushed into the generating flask. If the mouth of the funnel is only *just* below the surface of the water this cannot happen, for before the water reaches the stem of the funnel the mouth of the latter is out of water.

(C) Nitre is placed in the retort and just covered with concentrated sulphuric acid. The mixture is gently heated and the nitric acid distils, its vapour being condensed by the cold water and the damp filter paper which surround the collecting vessel. Brown fumes filling the retort are an indication that the temperature of the mixture in the retort is so high that some of the nitric acid has decomposed. Some of these 'nitrous' fumes dissolve in the acid collected and give it a brown colour.

Experiment 17.—(A) Place some granulated zinc in a test-tube and pour on it dilute hydrogen chloride. A gas is evolved which will burn. When the action has ceased, filter the solution into an evaporating basin and evaporate almost to dryness. Place the dish with its contents in a desiccator and leave it there for twenty-four hours.

(B) Perform a similar experiment, using copper oxide instead of zinc.

Experiment 18.—Remove the dishes from the

desiccator and leave them exposed to the air for half an hour.

Experiment 19.—Treat (a) copper and (b) zinc oxide with hot dilute hydrogen nitrate in evaporating dishes, adding the metal and oxide respectively to the acid till no more dissolve. Filter the solutions, if necessary, and evaporate till crystals form on cooling.

Questions :

1. What other names are given to hydrogen chloride solution and to nitric acid respectively ?

2. What is the reason for using a funnel in preparing a solution of such soluble gases as hydrogen chloride ?

3. What substances are left after the preparation of hydrogen chloride and hydrogen nitrate from rock salt and nitre respectively ?

4. What is the gas that comes off when zinc dissolves in hydrogen chloride, and what is the salt formed at the same time ?

5. What do you observe when this salt and the corresponding salt obtained from copper oxide are exposed to the air ?

6. What do you mean by 'deliquescence' ?

7. What are the salts obtained by dissolving copper and zinc oxide respectively in nitric acid ?

8. What is the meaning of the word 'desiccator,' and for what purpose is the instrument so termed employed ?

9. Define the terms 'solubility,' 'crystallisation.'

Preparation of Oxygen.

Experiment 20.—(A) Pour a small globule of mercury into an evaporating basin and cover it with dilute nitric acid. Heat the basin, and if the globule does not dissolve completely add more acid. Evaporate the solution and dry the crystals obtained.

(B) Place some of these crystals in a combustion test-tube fitted with a cork and a delivery tube which leads to a trough and under a boiling-tube filled with water. Fix the combustion-tube in a horizontal position and heat it, carefully observing all the changes that the crystals undergo. Continue heating till nothing remains in the bottom of the tube.

(C) Remove the boiling-tube from the trough by covering the end with the hand and dip a glowing chip into the gas.

(D) Collect the sublimate that remains in the combustion-tube.

The Properties of Oxygen

Demonstration.—Collection of three jars of oxygen. In these jars sulphur, charcoal, and sodium respectively are burnt, and the gases that remain are shaken up with water and the solutions formed tested with litmus solution.

Whereas sulphur burns with a pale blue flame in air, it burns with an intense blue violet flame in oxygen. The smell of sulphur burning in air is very noticeable, and slight white fumes appear in the gas jar which recall the white fumes produced when the vitriols are strongly heated. Blue litmus solution is immediately turned red when poured into the jar.

Charcoal too burns very rapidly, so much heat being given out that the mass becomes red hot; and a lambent blue flame plays over its surface scarcely noticeable when charcoal burns in air. Blue litmus solution turns wine red when shaken in the jar. But when this wine-red solution is boiled it turns blue again.

Sodium, if strongly heated, burns violently with an intense yellow flame. Red litmus solution when poured into the jar immediately turns blue and acquires a soapy feel.

Questions :

1. What are the crystals formed by the action of nitric acid on mercury ?

2. What are the names of the coloured powder, formed by the first heating of these crystals, and of the gas that is collected in the boiling-tube ?

3. How do you account for the action of the gas on a glowing splinter ?

4. What is the sublimate that forms in the combustion-tube ?

5. Why is the combustion-tube placed in a horizontal position before heating ?

6. From which of the substances used in Experiment 20 (A) comes the gas that is collected in the boiling-tube ?

7. What names would you give to the substances obtained by burning sulphur, charcoal, and sodium respectively in oxygen.

8. Which of these substances on solution in water forms an acid and which an alkali ?

(9) What substance would be formed if the solutions in the second and third of the collecting jars were mixed ?

10. Define the terms 'alkali,' 'acidic oxide,' 'basic oxide.'

TREATMENT OF CORK AND GLASS TUBING

Demonstration. — Cork boring, cork-borer sharpening, cutting and bending of glass tubing, cutting of corks to smaller diameter, the use of a wash-bottle.



Experiment 21.—Bore two corks respectively with one and two holes. Bend glass tubing at right angles and at an angle of 30° , and round off the ends. Insert a straight and a bent tube into a cork bored with two holes.

Experiment 22.—Fit up a wash-bottle. The nozzle must be attached to the outlet tube by

rubber tubing two inches long, so placed that it can be nipped between the first and second



fingers of the hand that holds the bottle. The neck must be covered with stout string, as at times the water in the bottle must be heated.

ALKALIS

Ammonia and its Properties

Experiment 23.—Heat sal-ammoniac—as much as will cover a threepenny piece—(a) with iron oxide, (b) with copper oxide, (c) with zinc oxide, and test the gas evolved with red litmus paper.

Experiment 24.—Prepare (a) a solution of ammonia gas, using similar apparatus to that employed in making the solution of hydrogen chloride, but without the *thistle* funnel, placing in the *round bottomed* flask a mixture of moist finely powdered sal-ammoniac with twice its bulk of lime, (b) a jar of the dry gas, collecting it by downward displacement of air. The gas is dried by passing it through a short horizontal tube containing pieces of quicklime.

Experiment 25.—(A) Invert the jar of gas prepared in Experiment 24 (b) in a trough of water coloured red with litmus.

(B) Pour some of the solution prepared in Experiment 24 (a) into three evaporating basins and add sulphuric acid, nitric acid, and hydrochloric acid respectively till the pungent smell disappears. Take out a drop of the mixed

solution with a glass rod successively from each basin and drop it on blue litmus paper. If this turns red add a few more drops of the alkaline solution and test again. When neither red litmus paper is turned blue nor blue litmus paper red by the mixed solutions evaporate them till portions cooled in a test-tube under the tap deposit crystals. Then cool the evaporating dishes and dry the crystals obtained between folds of filter paper.

Questions :

1. What is the action of sulphuric acid on sal-ammoniac ?

2. What is a basic oxide ?

3. What explanation can you offer of the action of iron oxide, copper oxide, and zinc oxide on sal-ammoniac ? What are the substances left in the test-tubes ?

4. How is it that the alkaline gas can be collected by downward displacement ?

5. Why is it that lime is chosen as the drying agent rather than another substance ?

6. Why is it necessary to round off the ends of glass tubes ?

7. Why must the mouth of the funnel be placed only just below the surface of the water

in the preparation of solutions of soluble gases ?

8. What are the crystals obtained by the action of the alkaline solution on sulphuric, nitric, and hydrochloric acids ?

9. Define the terms 'neutralisation,' 'mineral acid.'

10. What would you expect to be the action of heat on a mixture of lime with the sulphuric or hydrochloric acid salts prepared from the alkaline solution ?

11. What is left in the flask after Experiment 24 ?

Quicklime and other Alkaline Substances

Before 1755 the change that limestone undergoes on heating was supposed to be due to an absorption of fire particles, which made the body caustic. But on boiling caustic lime with washing soda this in its turn became caustic while the caustic lime was turned into limestone again. The 'mild' alkali, washing soda, was therefore thought to be an element, and the transference of causticity from lime to soda a mere transference of fire matter. Later, however, it was shown that ignition of limestone caused loss rather than gain in weight. In 1755 Joseph Black, Professor of Chemistry in the University of Edinburgh, wrote an account of experiments which cleared up the mystery. The following recall some of Black's experiments.

Experiment 26.—Place (*a*) some fragments of limestone, (*b*) some washing soda, in test-tubes, and cover them with dilute hydrogen chloride.

Questions :

1. What other chemical actions of a similar nature have you observed ?

2. What method that does not require the use of acid might you employ to cause the gas to come off ?

3. Do you notice any peculiarity about the crystals of washing soda ?

4. What do you mean by efflorescence.

Experiment 27.—(A) Place (*a*) a piece of limestone or marble, (*b*) crystals of washing soda, in test-tubes and heat strongly.

(B) Heat the same substances in crucibles in furnaces.

Experiment 28.—(A) Collect any powder that falls from the marble heated in Experiment 27 (B). Place it in a test-tube and add dilute hydrochloric acid.

(B) Treat the partially fused substance from washing soda also with acid.

Preparation and Properties of Quicklime

Demonstration.—(A) Heat limestone fiercely in a furnace fed with oxygen till there are no longer signs of escaping gas.

(B) Treat some of the powder obtained (a)



with water, (b) (after the addition of water) with dilute hydrochloric acid.

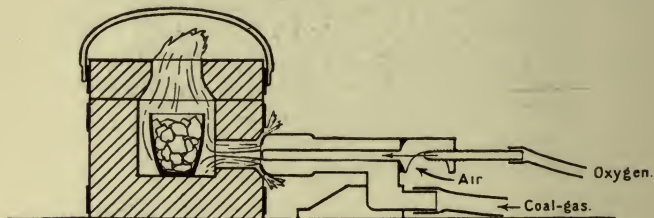
(C) Test a solution of the powder in water with red litmus paper.

The oxygen and some air, which passes with it through the central tube, only come in contact with the coal-gas at the orifice of the blowpipe, where, however, there is a thorough mixing. By the use of this instrument the combustion of inflammable gas is made much more rapid and complete than it is in the flame of an oil lamp or of a Bunsen burner. The lamp flame is supplied with air only at the sides

and edges, the Bunsen flame, due to rapid combustion of well mixed gas and air, contains very much nitrogen which does not assist combustion at all.

(A) The limestone or marble is placed in a clay crucible. After some time the fragments fall to powder, and a gas is evolved so rapidly that the surface of the powder is disturbed as though it were a liquid boiling. When there is no further evolution of gas the heating is stopped.

(B) (a) When water is dropped on to the powder



there is violent action. Some of the water passes away as vapour and a powder is left which to all appearance is as dry as ever.

(b) The powder dissolves and there is no evolution of gas.

(C) The solution of quicklime in water—lime water it is called—turns red litmus paper blue.

Questions :

1. How do you account for the different results obtained by treatment of limestone, before and after heating, with acid ?

2. What is the importance of the oxygen blast in producing a hot flame?

3. What is the substance produced by the addition of water to limestone after heating, and how do you account for the considerable heat produced?

4. What is the difference between 'quick' and 'slaked' lime?

5. Why is it that the action of acid on washing soda is the same before and after heating?

6. What should be the effect of boiling a solution of washing soda with roasted limestone?

7. What type of body is the roasted limestone?

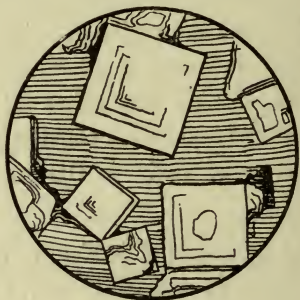
Experiment 29.—(A) Dissolve a teaspoonful of washing soda in water in an evaporating basin and add two teaspoonfuls of freshly prepared quicklime. Boil the solution for ten minutes and filter off the white powder that remains.

(B) Treat a portion of the solution and a portion of the white powder with dilute hydrogen chloride.

(C) Dip a finger in the solution and rub it over your thumb.

Experiment 30.—Neutralise (a) some solution of washing soda, (b) the remainder of the solu-

tion obtained in Experiment 29 (A) with dilute hydrogen chloride. Place one drop of each of the neutralised solutions on different parts of a microscope slide and allow the water to evaporate very slowly over the burner. Examine the residues under the microscope and draw carefully what you see, thus :



Evaporate the neutralised solutions till a film forms on the surface; cool, and dry the crystals that separate between folds of filter paper. Place a crystal from each solution successively on the tongue.

Questions :

1. How do you account for the change in the solution of washing soda and in the lime brought about by boiling them together ?

2. What type of body is that present in the solution of washing soda after boiling with lime?

3. What do you mean by an alkali?

4. What name would you give to the salts obtained by neutralising washing soda and its solution after treatment with lime with hydrogen chloride?

5. What is the crystalline form of these salts?

Experiment 31.—(A) Set up an apparatus similar to that used in the preparation of hydrochloric acid solution, place two tablespoonfuls of crushed limestone in the flask, just cover this with water and pour concentrated hydrochloric acid down the thistle funnel. Pass the gas that is evolved into solution of caustic soda placed in an evaporating dish, through a funnel, for twenty minutes. Evaporate the solution so obtained and dry the crystals that are deposited on cooling.

(B) Substitute a straight glass tube for the funnel and collect a jar of the gas by upward displacement of air. Hold a piece of magnesium ribbon (8 inches long) in the crucible tongs, light it and allow it to continue burning in the gas. Add dilute hydrogen chloride to the powder deposited and examine the residue carefully.

(C) Pass the gas through half a beaker-full

of lime water, bubble by bubble, for ten minutes. Boil the contents of the beaker for three or four minutes and filter off the precipitate. Dry this in the filter paper over a small flame. To a portion add dilute hydrochloric acid. Heat the remainder in a crucible in the Davies' furnace, and after cooling add to it a drop of water.

(D) To the crystals obtained in Experiment 31 (A) add hydrochloric acid. Evaporate the solution obtained and examine the crystals deposited, under the microscope.

Experiment 32.—(A) Make a solution of zinc sulphate—as much as will cover a penny—in a beaker, and to it add solution of sodium carbonate. Boil the mixture for three minutes, allow the white powder formed to settle, and then add more sodium carbonate solution. Boil the mixture and again add sodium carbonate solution, and so on till further addition causes no further precipitation. Filter off the white powder and evaporate the solution that passes through the filter paper till a portion cooled in a test-tube deposits crystals.

(B) Place some of the white substance on the filter paper in a test-tube and add dilute hydrogen sulphate.

Questions :

1. What is the gas that is evolved by the action of hydrogen chloride on marble? What are the salts left in solution in the flask and in the evaporating dish respectively?

2. What reason have you for thinking that the gas is composed of carbon and oxygen?

3. Explain the action of the gas on lime water. What happens when the white precipitate then formed is treated with acid, and when it is strongly heated?

4. What is the white substance formed by the action of sodium carbonate on zinc sulphate, and what is the salt left in solution?

5. What would be the effect of heat on the white substance?

Combination of an Alkali with Oxide of Sulphur

Experiment 33.—Repeat Experiment 31, A, B, and D—this time, however, charging the flask with sodium sulphite instead of with limestone and heating it gently.

Questions :

1. What evidence have you that the gas evolved by the action of hydrochloric acid on sodium sulphite contains sulphur and oxygen?

2. What are the names of the salts left in the flask and in the evaporating basins respectively ?

3. What class of bodies do this gas and the gas obtained by the action of hydrogen chloride on limestone belong to ?

In answering the following questions free use should be made of the notes.

1. What action has water on the oxides of sulphur, carbon, and sodium ?

2. Compare and contrast the properties of mercury, copper, iron, sodium, and zinc.

3. How are ammonia, ammonium sulphate, and ammonium chloride prepared on the manufacturing scale, and to what uses are they put ?

4. Suggest a method of separating the air into its various constituents.

5. To what substances are the names blende, pyrites, aqua fortis, spirits of salts, spirits of hartshorn, applied ?

6. What substances would you use for drying hydrochloric acid, oxygen, oxide of sulphur—and why ?

7. How are green and blue vitriol obtained on a large scale ?

8. Consider the various solubilities of gases.

9. What carbonates, sulphates, chlorides, and nitrates occur as minerals ?

10. What do you know of the composition of glass and porcelain respectively ?

11. Write some account of the action of hydrochloric acid on metals.

12. What occurs when mercuric nitrate, malachite, and rock salt are strongly heated ?

13. What do you mean by a hard water ? How could you make a soft water hard ?

14. What salts would you expect to be formed by passing carbonic acid gas and the oxide of sulphur over lime or zinc oxide ?

15. The white fume that is liberated by heating green vitriol is received in (a) solution of soda, (b) lime water, (c) sodium carbonate solution. What are the salts formed ?

16. What salts would be formed if ammonia gas was passed with carbonic acid gas and sulphur oxide into water ?

17. How do you explain the fact that a jet of coal-gas will burn in air ?

18. What are 'laughing gas,' Glauber's salt, Chili saltpetre, brass, bronze, zinc white, and quicklime ?

19. To what manufacturing purposes are

the various chemicals that you have used in the laboratory put ?

20. What methods can you suggest of preparing hydrogen and oxygen ?

21. Write an account of the ordinary gas flame, the Bunsen flame, the oxygen and the air blowpipe flames. How do you explain the different temperatures of these flames ?

22. What do you mean by neutralisation ? Illustrate your answer by reference to your own experience.

23. Give as many instances as you can (*a*) of combination, (*b*) of decomposition. Describe fully an experiment illustrating each phenomenon.

24. Describe the preparation of nitrogen, and illustrate your description with a diagram.

25. How do you account for this that carbon, sulphur, copper, and mercury are often found uncombined in nature, but hydrogen, iron, sodium seldom or never ?

EXAMINATION PAPERS

On finishing the book a pupil's knowledge should be tested by one of the following examination papers.

I

1. Define the terms acid, base, salt, deliquescence, efflorescence, sublimate, and illustrate your definitions by examples.

2. Compare and contrast the physical and chemical properties of mercury and zinc.

3. Describe the preparation and properties of sulphuric acid. Draw a careful diagram of the apparatus used.

4. Draw a diagram of the apparatus you would use to obtain nitrogen from the air, and write explanatory notes. What do you know of the other substance that would be formed during your experiment?

5. Limestone and quicklime dissolve in hydrochloric acid, the first with evolution of gas, the second without. Washing soda solution when mixed with the same acid evolves gas, but if first boiled with quicklime does not; the powder left after the boiling, however, does now effervesce with acids. Explain these phenomena.

6. What do you observe when a small quantity of the following substances are strongly heated in a glass tube: malachite, iron pyrites, sulphur, blue vitriol, limestone?

7. For what purposes are the following substances required in ordinary life: ammonium nitrate, ammonium sulphate, blue vitriol, and charcoal?

8. Define the term 'solubility of a gas' and write some account of the phenomenon, laying stress on the uses to which it may be put.

9. Write notes on air, ammonia, salts, and crystallisation.

10. By what other names do you know the following? as far as you can, explain their meanings: blende, caustic soda, green vitriol, sal-ammoniac, sulphuric acid, zinc oxide.

11. Give derivations for the words acid, carbon, copper, desiccator, nitrogen, malachite, porcelain, saltpetre.

II

1. Define the terms acidic oxide, basic oxide, alkali, oxidation, reduction, and illustrate your definitions by examples.

2. Compare and contrast the physical and chemical properties of copper and zinc.

3. Describe the preparation and properties of hydrochloric acid. Draw a careful diagram of the apparatus used.

4. Draw a diagram of the apparatus you would

use to produce a continuous stream of hydrogen, and write explanatory notes. Describe an experiment to illustrate the properties of the gas, and state what you know of the salt formed during its preparation.

5. Litharge, copper oxide, quicklime, when heated with sal-ammoniac, all cause the evolution of ammonia, being themselves converted into those salts which would have been left in solution had they been treated with hydrochloric acid. Explain these phenomena.

6. What do you observe when a small quantity of the following substances are strongly heated in a glass tube : siderite, blende, charcoal, green vitriol, sodium carbonate ?

7. For what purposes are the following substances required in ordinary life : green vitriol, nitre, nitric acid, and potassium sulphate ? How are they prepared ?

8. Define the term ' solubility of a salt ' and write some account of the phenomenon, laying stress on the uses to which it may be put.

9. Write notes on carbonic acid gas, evaporation, common salt, and metals.

10. By what other names do you know the following ? as far as you can, explain their meanings : blue vitriol, common salt, hydrochloric acid, nitre, siderite, sodium carbonate, iron pyrites.

11. Give derivations for the words alkali, chemistry, crystal, effervescence, hydrogen, mercury, pyrites.

III

1. Define the terms element, compound mixture, specific gravity, density, evaporation, and illustrate your definitions by examples.

2. Compare and contrast the physical and chemical properties of iron and sodium.

3. Describe the preparation and properties of nitric acid. Draw a careful diagram of the apparatus used.

4. Draw a diagram of the apparatus used to prepare oxygen, and write explanatory notes. Describe an experiment to illustrate the properties of the gas, and state what you know of other substances formed during its preparation.

5. Hydrogen chloride and hydrogen sulphate dissolve zinc oxide and copper oxide without the evolution of gas: the metals zinc and iron dissolve in hydrogen chloride and hydrogen sulphate to form the same or similar salts to those previously obtained, but without evolution of gas. Explain these phenomena.

6. What do you observe when a small quantity of the following substances are strongly heated in a glass tube: calamine, copper pyrites, rock salt, white vitriol, sal-ammoniac?

7. For what purposes are the following substances required in ordinary life: quicklime, sodium carbonate, sodium sulphate, white vitriol, zinc oxide? How are they prepared?

8. Write an account of the actions of acids, alkalis, and water on solid substances. Explain the actions that occur.

9. Write notes on filtration, glass, non-metals, and coal-gas.

10. By what other names do you know the following? as far as you can, explain their meanings: calamine, copper pyrites, iron oxide, nitric acid, quicklime, sodium sulphate, white vitriol.

11. Give derivations for the words azote, deliquescence, efflorescence, magnesium, oxygen, sal-ammoniac, sublime.

NOTES

(All temperatures are given on the Centigrade scale.)

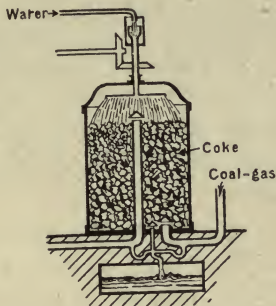
1. Acid.—A body containing hydrogen that can be replaced by a metal: it has a sour taste and turns blue litmus red. Some acids are gases, like hydrochloric acid; some liquid, like sulphuric and nitric acids; some solid, like tartaric acid.

2. Acidic Oxide.—An oxide that combines with water to form an acid. The oxides of sulphur and carbon are acidic oxides.

3. Air.—A mixture of one volume of oxygen with four volumes of nitrogen containing rather less than one per cent. of argon. Air contains also varying quantities of carbonic acid gas and water vapour: both are necessary to the life of plants, and water vapour is necessary to the life of animals. Air is 14.4 times as heavy as hydrogen; 1000 c.c. of it weigh 1.293 grams. Liquid air has a temperature of -190° , and when it boils the gas that first escapes is mostly nitrogen, which boils at a lower temperature than oxygen. Coal-gas burns in air because the carbon and hydrogen of the coal-gas combine with the oxygen of the air—a jet of air will burn equally well in coal-gas.

4. Alkali.—The solution of a basic oxide in water. A solution of sodium oxide in water is an alkali called caustic soda. Ammonia gas combines with water to form an alkali called ammonium hydrate. Alkalis neutralise acids and turn red litmus blue.

5. Ammonia.—This gas for long was known only as an aqueous solution, ‘spirits of hartshorn,’ obtained by heating sal-ammoniac— itself made by the dry distillation of horns, hoofs, etc.—with lime. Ammonia readily combines with acids, forming ammonium salts. It is present in the gas obtained by the distillation of coal, and is separated from this by passing through water.



(After Roscoe and Schorlemmer.)

When the solution is neutralised with dilute sulphuric acid and evaporated, ammonium sulphate crystals are obtained. These crystals are the chief source of the ammonia of commerce. Liquefied ammonia has a temperature of -40° . The gas is very soluble in water (1 c.c. of water dissolves 1270 c.c. of gas at 0°) and its solution is strongly alkaline.

6. Ammonium Nitrate.—A salt prepared by neutralising nitric acid with ammonia. It is very

soluble in water, causing considerable reduction in temperature. The 'laughing gas' used by dentists is prepared by heating this salt.

7. Ammonium Sulphate.—A salt prepared in great quantities by heating the ammoniacal liquor of the gasworks with lime, and passing the gas evolved into dilute sulphuric acid. It is soluble in water and is used as a manure and also for the preparation of other ammonium salts.

8. Base.—A body which like copper oxide or zinc oxide neutralises an acid with production of a salt and water only. Carbonates and some other salts will neutralise acids, but they are not therefore bases.

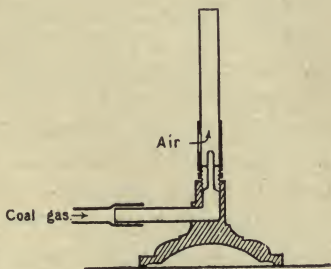
9. Basic Oxide.—An oxide that neutralises an acid, forming a salt and water. The oxides of copper, magnesium, and zinc are basic oxides.

10. Blende.—When the natural sulphide of zinc was found to contain no lead it was called *blind* (i.e. false lead ore). In the pure state blende is transparent and has a light yellow colour—usually it contains iron and other metals which impart to it a red, brown, or black tint.

11. Blue Vitriol.—Copper sulphate or copper vitriol has been long known, as it is found in the drainage water of copper mines. Its artificial production was first described in 1644: copper and

sulphur were heated together and the residue moistened with rain water. The salt is now produced on the large scale by roasting copper pyrites, when the copper sulphide is oxidised to copper sulphate ; this is dissolved from the mass by treatment with water. Copper sulphate is also formed when copper is treated with hot concentrated sulphuric acid. The blue crystals lose water when heated to 260° and fall to a white powder ; and this white powder will immediately combine with any water it may meet, turning blue again. Copper sulphate is used in agriculture and in electroplating.

12. Bunsen Burner.—When a jet of coal-gas is raised to a certain temperature the carbon and hydrogen it contains combine with oxygen from the air ; and so much heat is produced that adjoining portions of coal-gas likewise *take fire* and the flame is continuous. White hot particles of carbon, for the moment unconsumed, make the flame luminous. But it is only the surface of the jet that can obtain the supply of air necessary for its combustion. When coal-gas issues from the jet at the bottom of a Bunsen



tube it carries with it some air : more air passes in, and indeed sufficient to allow complete and almost immediate combustion of the coal-gas at the top of the tube. The carbon combined with hydrogen in coal-gas is converted into carbonic acid gas and so the flame is almost invisible. Nevertheless it is intensely hot.

13. Calamine.—Zinc spar or calamine is a carbonate of zinc : it is white when pure, but frequently has a rusty colour due to the presence of iron oxide. It is found in Great Britain at Alston Moor, Lead Hills, and Matlock, and in Donegal. On heating, it gives up carbonic acid gas, and zinc oxide is left. It readily dissolves in acids, forming zinc salts, with evolution of carbonic acid gas.

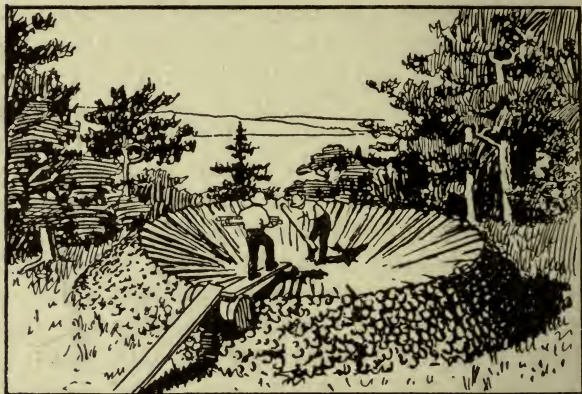
14. Carbon.—This element is found naturally only in the crystalline form, as diamond in sundry river deposits in South Africa, Brazil, and India, and as graphite in lumps or nodules in crystalline rocks. Graphite is found in small quantities at Borrowdale, in Cumberland ; in the great mines of California the layer is 20–30 feet thick. As salt dissolved in hot water often separates as crystals when the solution cools, so carbon dissolved in molten iron separates under chosen circumstances as diamond or as graphite. Diamond and graphite burn in air or oxygen when their temperature is raised sufficiently, and form carbonic acid gas. Diamond is the hardest substance known and, like graphite, is not affected by acids or alkalis. Carbon is obtained in the non-crystalline

form by heating animal and vegetable substances in a supply of air insufficient to burn them completely. Lamp-black, gas carbon, and charcoal are different forms of this non-crystalline or amorphous carbon. Coal contains from 80–90 per cent., coke 91 per cent. of carbon.

15. Carbonic Acid Gas.—Carbon dioxide or carbonic acid gas is the gas that escapes from effervescing mineral waters, and is present in small but varying quantities in the air. In the presence of sunlight the green leaves of plants can take the carbon from carbon dioxide, oxygen being given back to the air. Animals breathe out carbon dioxide, and this gas is the choke-damp left after explosion in mines. It is given off in large quantities during fermentation and is readily prepared by the action of acids on carbonates. Carbon dioxide is colourless and possesses a slightly pungent smell and acid taste: it is readily converted into a liquid which boils at -78.2° . It is soluble in an equal volume of water at the ordinary temperatures of the air (about 15°).

16. Caustic Soda.—Sodium hydroxide or sodium hydrate is made by dissolving sodium in water or by boiling sodium carbonate solution with slaked lime. It is a powerful alkali and very soluble in water. When fused it attacks most metals, and it combines readily with glass and porcelain. Carbonic acid gas dissolves in it, forming sodium carbonate.

17. Charcoal.—Charcoal is prepared by heating wood with admission of as little air as possible, and consists almost entirely of carbon. Powdered charcoal sinks in water, but lumps of it float because of the air contained in the pores. Charcoal readily absorbs gases and colouring matter from liquids, and



PREPARATION OF CHARCOAL

[After Mellor.]

is therefore used for disinfecting the air of hospital wards; it is also used in filters. Charcoal burns in air, forming carbon dioxide; but if the supply of air is not good, another and very poisonous gas, carbon monoxide, is produced.

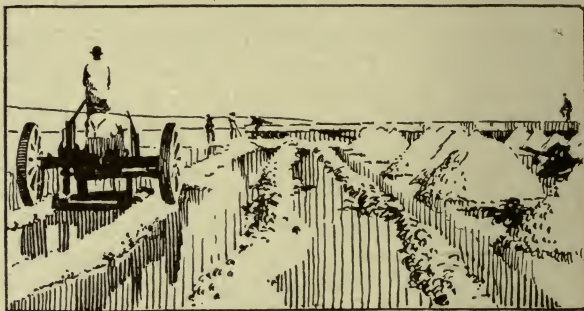
18. Coal-Gas.—A mixture of gases—viz. hydrogen, an oxide of carbon which contains less oxygen than carbonic acid gas, and various compounds of carbon

with hydrogen. It is made by heating coal in iron crucibles, and is then purified by passing through water which dissolves ammonia, and over lime which absorbs various sulphur compounds.

19. Combination.—The union of two or more elements or compounds to form a substance with properties quite different from those of its constituents. Combination generally results in the giving out of heat, sometimes of light. It is part of the chemist's business to discover the circumstances under which combinations occur, to discover, that is, the chemical properties of substances. Elements generally combine with elements, compounds with compounds; thus iron combines with sulphur, carbon with oxygen, carbonic acid gas with caustic soda, sodium carbonate with water. But sometimes compounds combine with elements, as when iron pyrites and copper pyrites combine with oxygen in the presence of water to form Green and Blue vitriol respectively.

20. Common Salt.—At the dawn of History, salt had an established place in the household economy of civilised peoples; to eat no salt was to confess barbarism. Salt (sodium chloride) is found in the earth as rock salt, or is prepared by evaporating sea water, or the brine from salt lakes or springs. To the great bulk of mankind it is a luxury, and to vast numbers an unattainable luxury. It is only in Europe that Nature has been prodigal of her gift

over widespread areas. The most extensive deposit perhaps in the world is that which stretches for 500 miles along the Carpathian mountains, striking out laterally for 100 miles with a thickness in some places of 1200 feet. Numerous salt lakes precipitate



great masses of salt during the heat of every summer. The sea contains an inexhaustible fund of salt and provides half the supply of the world. Salt is almost equally soluble in hot and cold water. It crystallises in cubes, melts at 801° , and boils at 1750° .

21. Compound.—A body made up of two or more elements in fixed proportions by weight. It does not resemble its components, into which it cannot be split up by mechanical means. Water, for example, is invariably made up of 8 parts by weight of oxygen to 1 part of hydrogen; it is quite unlike either oxygen or hydrogen in properties, and if distilled or crystallised undergoes no change in composition.

22. Copper.—This metal occurs in the native state near Lake Superior, in Cornwall, the Faroe Islands, Siberia, and the Urals. It was used in primitive times for making weapons, ornaments, and utensils. Copper is one of the best conductors of heat and electricity. It is very malleable, and can be rolled or hammered into thin leaf (Dutch metal). It has a specific gravity of 8.94 and melts at 1080.5° . It can be distilled as a green vapour in the electric furnace. On passing from the liquid to the solid state copper expands. Copper is unaffected by dry air: it is not attacked by hydrochloric or sulphuric acid in the cold, but hot sulphuric acid and nitric acid dissolve it readily. Brass is an alloy of copper and zinc, bronze an alloy of copper and tin.

23. Copper Oxide.—A basic oxide made by heating the nitrate or carbonate of copper or by heating copper in air. It is used for colouring glass a fine light green. It is readily soluble in the mineral acids, forming solutions of the copper salts.

24. Copper Pyrites.—A sulphide of iron and copper—the larger the percentage of copper the more golden is the yellow tint of the mineral. It can be distinguished from iron pyrites by the ease with which it is scratched by a knife.

25. Crystallisation.—The process of forming crystals. The body that is to crystallise must, as a rule, be in the liquid state, either fused or in solution, that its smallest parts may have freedom to fit in

the definite regular arrangement which is the essential feature of a crystalline substance.

26. Decomposition.—The breaking up of a compound into its constituent elements or into other compounds. A rise in temperature is frequently the cause of decomposition, as when oxide of mercury breaks up into oxygen and mercury, blue vitriol into copper oxide, an oxide of sulphur, and water. There is a phenomenon which is of very frequent occurrence and which chemists call *Double Decomposition*. Two compounds exchange their corresponding parts : thus the mixing of copper oxide with hydrogen sulphate results in the formation of hydrogen oxide or water and copper sulphate, the mixing of sodium carbonate and zinc sulphate, both in solution, in the formation of zinc carbonate and sodium sulphate, the mixing of potassium nitrate with hydrogen sulphate in the formation of potassium sulphate and hydrogen nitrate. If substances meet in solution and one of the products of double decomposition is insoluble in water a *precipitate* is formed.

27. Deliquescence.—The phenomenon of a salt taking up moisture, becoming pasty and often liquid, when exposed to the air. The chlorides of zinc and copper very readily deliquesce. Deliquescent salts are very soluble in water.

28. Density.—This term, as applied to solids and liquids, means the mass of one or the other per unit volume. Thus by saying that the density of copper

is 8.94 we mean that 1 c.c. of copper weighs 8.94 grammes.

29. Desiccator.—An apparatus containing some drying agent—usually sulphuric acid—in which a liquid or solid may be kept to hasten its drying or, if deliquescent, to preserve it in a dry state. Any moisture given off by the liquid or solid is immediately absorbed by the drying agent.

30. Drying Agent.—A substance that absorbs or combines with water readily and which can therefore be used to dry gases or liquids. Quicklime or solid caustic soda will dry an alkaline gas like ammonia, concentrated sulphuric acid will dry carbonic acid gas and hydrochloric acid, also such a liquid as nitric acid. Dry deliquescent salts like calcium chloride or zinc chloride can also be used in many cases. But an alkaline substance must not be used to dry an acid nor an acid substance to dry an alkali.

31. Effervescence.—The bubbling and disturbance due to the escape of a gas. Such occurs when a mineral acid is poured on to zinc or carbonate of lime, and when concentrated sulphuric acid is poured on to rock salt.

32. Efflorescence.—The phenomenon of a salt giving up combined water when exposed to the air and in consequence gradually falling to powder. Transparent crystals of washing soda rapidly become covered with a white incrustation when so exposed.

33. Element.—A body like copper, sulphur, or mercury, which cannot be split up into anything simpler than itself.

34. Evaporation.—This occurs only at the surface of a liquid (or solid) and at all temperatures. The rate of evaporation is proportional to the *area* of liquid exposed to the air. Thus a liquid boiling in a flask evaporates no more quickly than it would in a test-tube, the area of whose cross-section is equal to the area of the cross-section of the neck of the flask.

35. Filtration.—The passing of a liquid through a porous substance, charcoal or unglazed paper, whereby *suspended* matter is separated from the liquid, the particles being larger than the pores through which the latter passes.

36. Glass.—A mixture made by heating sand, lime, and carbonate of soda or potash together. Sand or silica is an acid-forming oxide which combines with bases on being fused with them to form salts called silicates. Pure glass is transparent and colourless. It becomes soft at a red heat and at higher temperatures melts, and the more readily the smaller its percentage of silica. Glass is attacked by water and acids, and readily by alkalis.

37. Green Vitriol.—Ferrous sulphate is often found in solution in drainage water from mines. About a hundred tons per week are manufactured in South Lancashire by exposing heaps of iron

pyrites to the atmosphere and crystallising the solution obtained by washing. It can readily be prepared in the laboratory by dissolving iron in dilute sulphuric acid. It is used in the preparation of inks and prussian blue.

38. Hydrochloric Acid.—Spirits of salt, muriatic acid, or hydrogen chloride was first prepared in 1648 by the method now used, by acting on rock salt with sulphuric acid. Hydrogen chloride is a colourless, pungent gas which fumes in moist air, and is very soluble in water (1 volume of water absorbs 503 volumes of hydrogen chloride at 0°). It is a solution of the gas in water which is sold as hydrochloric acid. Hydrochloric acid is composed of hydrogen and the green gas chlorine. It dissolves many of the metals, forming chlorides: the metal takes the place of the hydrogen which is consequently liberated.

39. Hydrogen.—An inflammable gas prepared by the action of many metals on dilute sulphuric and hydrochloric acids. It is the lightest gas known, being 14.4 times lighter than air. When hydrogen burns in air it combines with oxygen to form water, and when passed over the heated oxides of copper and iron it combines with the oxygen and leaves the metals. It has neither taste nor smell and is almost insoluble in water.

40. Inference.—The conclusion that is come to after considering the results of an experiment or experiments.

41. Iron.—Nearly all meteorites contain iron associated with other metals, chiefly copper, cobalt, and nickel, and among primitive peoples they are used for the manufacture of weapons. Iron is readily attacked by moist air and so is seldom found native. It is obtained by heating its ores—carbonates or oxides—with coal or charcoal in a furnace through which a blast of air is made to pass that the coal may burn more quickly and give off greater heat. A rude form of blast-furnace is used by the Hill tribes of Central India and the natives of Central Africa. Cast iron, wrought iron, and steel vary in the amount of carbon they contain: cast iron contains the most (3 per cent.), wrought iron the least (0·06 per cent.). Wrought iron melts at about 1500° , but softens about 1000° and can then be fused and welded. Cast iron melts about 1200° . Iron is readily dissolved by the dilute mineral acids, and if red hot will combine with the oxygen of steam, releasing hydrogen.

42. Iron Oxide.—Is found in nature as red hæmatite and as specular iron, two of the most important ores of iron. It is the body left after ignition of green vitriol. It dissolves but slowly in acids.

43. Iron Pyrites.—This mineral was known in early times as *purites*. It has a brassy yellow colour and a specific gravity of 5·185, and is very hard, giving sparks when struck with steel. It occurs in all geological formations. Great masses

occur in Andalusia and the adjoining parts of Portugal. At the Tharsis Mine there are four masses, two of which are 2600 yards long and 200 yards across : their depth has not been determined.

44. Limestone.—This body is one form of calcium carbonate, a salt which constitutes the greater part of egg-shells, shells of mollusca, and coral. A limestone hard and close-grained enough to take a polish is called marble.

45. Litmus.—Blue colouring-matter got from lichens. It is turned red by acids, but the blue colour returns on the addition of an alkali.

46. Magnesium.—This metal can be prepared by heating the fused chloride of magnesium with sodium, when sodium chloride is formed and magnesium separates. Magnesium is a white metal which melts at 632.7° and boils about 1100° . It is 1.75 times as heavy as water. Magnesium in moist air becomes covered with a film of oxide and is dissolved very readily by acids. It burns with a very brilliant light and is therefore much used in photography, signalling, and in the preparation of fireworks.

47. Malachite.—Carbonate of copper is a bright green mineral which is found in the Urals, at Chessy in France, in Cornwall and Cumberland, accompanying other copper ores. It is a very valuable source of copper. On heating, it is converted into oxide of copper, with evolution of carbonic acid gas.

The same gas is produced when malachite dissolves in acids, salts of copper being formed at the same time.

48. Mercury.—This metal has been known certainly since 300 B.C. and occurs in the native state. Its most important ore is the sulphide or cinnabar from which it is obtained by heating with lime. Some of the most celebrated mines are those of Idria in Carniola and of Almaden in Spain. Mercury is 13·6 times as heavy as water, and all solid bodies except gold and some of the rarer metals float on its surface. It freezes at $-38\cdot85^{\circ}$ and boils at 360° . Mercury dissolves in nitric acid and in hot concentrated sulphuric acid. It dissolves gold and silver readily, and combines with many other metals to form amalgams.

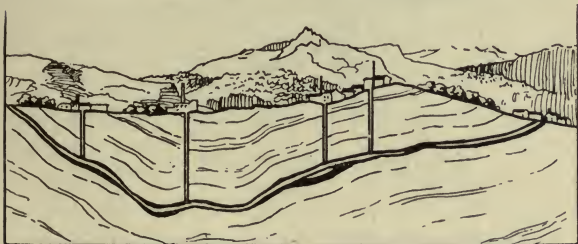
49. Mercuric Nitrate.—A deliquescent salt prepared by boiling mercury with nitric acid. On heating, it decomposes, oxygen being evolved mixed with brown fumes; mercuric oxide is left, and on further heating is decomposed into mercury and oxygen.

50. Mercuric Oxide.—A red powder which can be obtained as a scum on the surface of mercury kept just below the boiling-point. It is prepared on the large scale by heating a mixture of mercury and mercuric nitrate. It is a powerful poison and is slightly soluble in water.

51. Metal.—An element which combined with oxygen forms a basic oxide. It is a good conductor

of heat and electricity, and generally can be beaten into plates—is malleable—and drawn into wire—is ductile. Its clean surface has metallic lustre.

52. Mineral.—A substance obtained by mining, sometimes in underground excavations, sometimes



A BED OR STRATUM OF COAL

[After Bristow]



VEINS OF SIDERITE

[After Bristow]

in open workings. Minerals occur in beds or strata, in veins or lodes, or in deposits of irregular shape.



HÆMATITE (OXIDE OF IRON) REPLACING
LIMESTONE

53. Mineral Acid.—There are three so-called mineral acids—sulphuric acid, nitric acid, and hydrochloric acid. Sulphuric acid was first prepared by heating the mineral green vitriol and condensing the white fumes evolved, nitric and hydrochloric acids by treating the minerals nitre or saltpetre and rock salt with sulphuric acid. Mineral acids are to be distinguished from such vegetable acids as tartaric acid, citric acid, acetic and oxalic acids, which are obtained from vegetable substance.

54. Mixture.—A body made up of two or more elements or compounds in varying proportions by weight: it resembles its components in properties, and these can be separated by mechanical means. Thus air contains about 23 per cent. by weight of oxygen, but sometimes it contains a little more, some-

times a little less. Its solution in water contains more oxygen than 23 per cent., because oxygen is more soluble than nitrogen ; and when air is liquefied, the first gas that escapes from the liquid is almost pure nitrogen.

55. Mother Liquor.—A solution from which crystals have been deposited, and which will continue to deposit crystals as more of the solvent evaporates.

56. Neutralisation.—The phenomenon of an acid losing its acidity, or of an alkali losing its alkaline character in consequence of the one or the other being converted into a salt. Caustic soda solution turns red litmus blue, hydrochloric acid turns blue litmus red. If the one is added to the other in just the right proportion, the resulting solution will turn neither red litmus blue nor blue litmus red. There is now nothing in solution but sodium chloride which is *neutral*.

57. Nitre.—Saltpetre or potassium nitrate is found as an efflorescence on the walls of stables and in the soil in hot countries near recently inhabited villages, being formed by the chemical change of animal substance. In Ceylon and different parts of India, nitre is obtained by the washing of certain porous rocks : hence its name *sal-petra*. It is made commercially by combining the oxygen and nitrogen of the air in presence of potash. There is a nitrate of sodium called Chili saltpetre, which is found in large quantities in the rainless districts of Peru and

Bolivia, and by mixing a solution of this salt with a solution of potassium chloride ordinary saltpetre is obtained. Nitre is one of the ingredients of gunpowder: the oxygen which it contains combines with the other ingredients, sulphur and charcoal, to form the gases that cause the explosion.

58. Nitric Acid.—Aqua fortis or hydrogen nitrate was prepared in early times by heating a mixture of saltpetre, alum, and sulphate of copper. It is now prepared by heating nitre with an equal weight of sulphuric acid. It is a liquid which begins to boil at 86° , partly breaking up then into water, oxygen, and a brown gas that contains both nitrogen and oxygen. Nitric acid attacks many metals readily, nitrates being formed. It dissolves sulphur, converting it into sulphuric acid. It is very largely used for making explosives—gun-cotton, nitroglycerine, picric acid, etc.

59. Nitrogen.—When oxygen is removed from the air by passage over hot copper, the gas that remains is almost pure nitrogen. Two years before the discovery of oxygen, in 1772, it was found that air in which animals had breathed, even after the products of respiration had been absorbed, was incapable of supporting combustion, and in consequence for many years this air was called *azote*. Nitrogen is an essential element in the bodies of animals and vegetables. It is fourteen times as heavy as hydrogen, has neither taste nor smell and is almost insoluble in water.

60. Non-Metal.—An element which, combined with oxygen, forms an acidic oxide, which, moreover, has none of those properties, malleability, ductility, metallic lustre, etc., by which a metal is recognised. Oxygen, carbon, and sulphur are non-metals.

61. Oxidation.—A body that by some means or other is made to combine with oxygen is said to be oxidised. So copper is oxidised by being heated in a current of air, mercury by the ignition of the salt which it forms on solution in nitric acid.

62. Oxide.—A compound formed by the union of an element with oxygen. All the metals form basic oxides, most of the non-metals acidic oxides.

63. Oxygen.—The greater part of the earth's crust contains about 47 per cent. of oxygen; 88 per cent. of water and 23 per cent. of air is oxygen. Animals breathe to supply their blood with this gas, and its presence in water (4 volumes dissolve in 100 volumes of water) is necessary to the life of fishes. It is by combining with oxygen that wood, coal, paper, etc., burn.

Oxygen was discovered by Dr. Priestley in 1774. It can be prepared by heating mercuric oxide, or more readily and more economically by heating a mixture of manganese dioxide and potassium chlorate; but when required in large quantities it is obtained from the air. It has neither taste nor smell, and is sixteen times as heavy as hydrogen.

64. Phenomenon.—Anything that appears or is perceived. The word is used especially for a thing the cause of which is in question. The blue flame playing over the surface of iron pyrites heated in air is a phenomenon, so too is the reddening of blue litmus by an acid, so too the precipitate which falls when carbonic acid gas is passed into lime water.

65. Porcelain.—The substance made by strongly heating a mixture of clay and a silicate of potash called felspar. The fused felspar fills the pores of the infusible clay.

66. Potassium Sulphate.—This salt was first obtained from the residues of the manufacture of nitric acid or aqua fortis. It is soluble in water, and is used as a purgative.

67. Quicklime.—Calcium oxide is made on the large scale by burning a mixture of limestone with coal or other combustible matter. It is a white substance without crystalline form, which will only melt in the great heat of the electric furnace. It is used in the preparation of mortars and cements, for drying gases, and in the preparation of bleaching powder.

68. Reduction.—A body that has oxygen taken from it, whether by the action of hydrogen or of charcoal or other substance, is said to be reduced. So copper oxide is reduced when heated in a current of hydrogen, iron oxide when heated with charcoal.

69. Sal-ammoniac.—Chloride of ammonia has been known for a long time, and appears to have been brought to Europe in the seventh century from the volcanoes of Central Asia. At one time it was the source of all the ammonium salts. Sal-ammoniac is prepared to-day by distilling the water through which crude coal-gas has been passed with lime, and passing the gas evolved into hydrochloric acid; or by heating a mixture of ammonium sulphate and common salt, when ammonium chloride sublimes and is condensed in the dome-like cover of the apparatus used. The salt is colourless and odourless, and has a sharp saline taste. One part dissolves in ten parts of water at 13.3° , and the temperature of the liquid is reduced thereby to -5.1° .

70. Salt.—A body formed by the replacement of the hydrogen of an acid by a metal. Many salts are soluble in water like common salt and blue vitriol, and have a definite crystalline form. Some, like Iceland spar and galena, are not soluble in water but yet have crystalline form; some are not soluble in water and have no crystalline form, like precipitated chalk. Most of the salts not soluble in water are soluble in acids.

71. Siderite.—Spathic iron ore or siderite is a carbonate of iron and is found in Somerset, Devonshire, and Yorkshire. The most celebrated mines are those of Erzberg in Styria, where not less than 110,000 tons of ore are raised each year for the

manufacture of Styrian steel. Spathic iron ore has a yellowish brown colour and on heating readily gives, off carbonic acid gas leaving the red oxide of iron. Acids dissolve it, forming salts of iron with evolution of carbonic acid gas.

72. Slaked Lime.—When water is poured on quicklime combination takes place with great evolution of heat—the temperature sometimes rising to 150° . This process is called slaking. Slaked lime is soluble in water, more so in cold than in hot, and the solution, lime water, combines readily with carbonic acid gas, forming a white precipitate of calcium carbonate.

73. Sodium.—The soft white metal contained in carbonate of soda, caustic soda, and salt. It was first obtained in 1807 by the passage of an electric current through fused caustic soda ; then by heating carbonate of soda with carbon ; now by passing an electric current through fused common salt. Sodium attacks water readily, forming caustic soda and liberating hydrogen, and dissolves in acids forming salts of sodium. It combines so readily with the oxygen of the air that it must be kept under rock oil. It melts at 95.6° and boils at 742° .

74. Sodium Carbonate or Soda-ash.—This is a salt of great importance and is used in the manufacture of soap and glass. The world's production amounts to a million tons per annum or thereabouts.

Previous to 1793 the whole of the soda of commerce was obtained from the ashes of sea plants ; but the bulk of the alkali used came as potassium carbonate from Russia and America, where it was obtained from the ashes of land plants. The French Revolution caused a blockade of the French coast, and means were sought to make soda-ash from common salt. The process of heating sodium sulphate (itself produced from salt by the action of sulphuric acid) with coal and limestone was found to be the most satisfactory. Sodium carbonate is soluble in water, and more so in hot than in cold. It combines with carbonic acid gas to form the bicarbonate of soda used in cookery. This body liberates carbonic acid gas when heated, and so cakes, etc., are made porous.

75. Sodium Sulphate.—A salt prepared by the action of sulphuric acid on common salt. The crystals which separate when its solution in water slowly evaporates contain combined water, and are called Glauber's salts—an aperient which at one time was believed to have most valuable medicinal properties. The crystals are efflorescent.

76. Sodium Sulphite.—A colourless salt soluble in water, prepared by dissolving sulphur dioxide in caustic soda. On the addition of acid, sulphur dioxide is evolved and a salt of sodium formed. It combines with more sulphur dioxide to form sodium metabisulphite.

77. Solubility.—Substances, whether solid, liquid, or gas, display very different solubilities in water. Thus while 100 grammes of water will dissolve 203 grammes of cane sugar at 18° , it will only dissolve 0.00025 gramme of barium sulphate. Alcohol mixes with water in all proportions, but if ether and water are shaken together and the mixture be then allowed to stand, the top layer contains 3 per cent. of water only, the bottom layer 10 per cent. of ether. One volume of water dissolves 1270 volumes of ammonia at 0° , it will only dissolve 0.0226 volume of hydrogen. Solids generally are more soluble in hot than in cold water, but common salt is almost equally soluble in water at the boiling and at the freezing point. Gases invariably are less soluble in hot than in cold water.

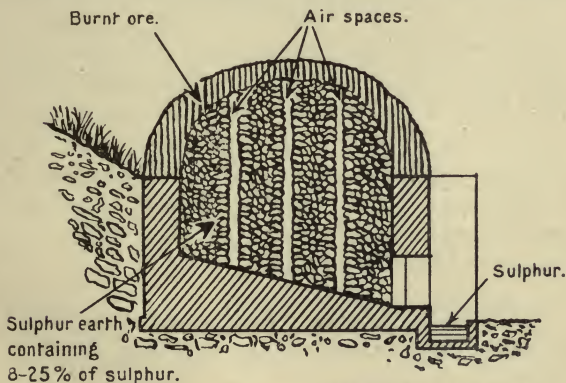
The number of grammes that dissolve in 100 grammes of water at a given temperature is the measure of the solubility of a solid; the number of volumes that dissolve in 1 volume of water at a given temperature is the measure of the solubility of a gas.

78. Specific Gravity.—The number of times a given solid or liquid is heavier than an equal volume of water. Thus the specific gravity of mercury is 13.6—i.e. one volume of mercury is 13.6 times as heavy as one volume of water. The number of times a given volume of gas is heavier than an equal volume of air, at the same temperature and pressure, is sometimes spoken of as the specific gravity of the gas: it is more usual, however, to speak of the

density of a gas—the number of times it is heavier than an equal volume of hydrogen.

79. Sublimate.—The deposit formed on a cool surface when some substances are heated. A sublimate when heated resublims without decomposition. Sal-ammoniac when heated in a test-tube sublimes—passes from hotter to cooler parts of the tube without liquefying.

80. Sulphur.—An element which is found uncombined in large quantities. Almost all the native



[After Roscoe and Schorlemmer

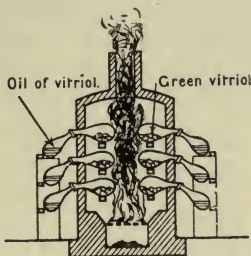
sulphur of commerce comes from Italy and from Sicily, where the output in the year 1899 amounted to 416,446 tons. The accompanying diagram shows the manner of its preparation. The stacked earth is lighted near the bottom, and the heat of the burning

sulphur melts the remaining sulphur out of the ore. Mount Purace in Colombia wears a cap of sulphur (derived from its own crater) which accumulates at the rate of about two feet per annum, and has a superficial area amounting to 1435 square yards. Sulphur has a specific gravity, of 2.05 and melts at 114.5° to a clear yellow liquid. It is insoluble in water, but soluble in carbon bisulphide, petroleum, and turpentine.

81. Sulphur Dioxide.—This is the gas formed when sulphur burns in air or oxygen and when mineral sulphides are burnt in air. It is usually prepared in the laboratory by heating copper with concentrated sulphuric acid. It is a colourless gas, heavier than air: it is very soluble in water, 1 volume of water at 20° dissolving 39.3 volumes of the gas. The solution is called sulphurous acid. When dissolved in alkalis it forms sulphites. Sulphur dioxide is readily liquefied and boils at -8° . It bleaches damp vegetable colouring matter.

82. Sulphuric Acid.—Vitriolic acid or hydrogen sulphate was obtained at one time exclusively by heating green vitriol, and hence the name 'oil of vitriol' or 'vitriolic acid.' It is now prepared by another method and on an enormous scale, 850,000 tons and more being produced annually in Great Britain alone. Pure sulphuric acid when cooled forms crystals which melt at 10.5° . The pure liquid has a specific gravity of 1.837 and boils at 338° .

Concentrated sulphuric acid combines very readily with water and great heat results. It attacks the skin dangerously, and must be used with great



caution. It dissolves many metals, which take the place of hydrogen in the acid and forms salts called sulphates.

83. Vitriol.—A body of a glassy appearance, so called from the Latin word *vitrum*, meaning glass. In earlier times, when the compounds known were comparatively few in number, bodies were classified according to some obvious physical feature—thus there were spirits, as of wine, of hartshorn, of salt, butters, oils, vitriols, etc.

84. Water.—A compound of 8 parts by weight or 1 part by volume of oxygen with 1 part by weight or 2 parts by volume of hydrogen. It was not till 1781 that water was discovered to be compound. Water can be prepared by mixing its constituent gases together and lighting them, by burning a

jet of hydrogen in air, by passing a stream of hydrogen over many heated metallic oxides. The purest form of natural water is rain water. Sea water is saline from the salts which streams dissolve from the ground on their passage to the sea. Hard waters—waters that will not lather with soap—contain salts of lime and magnesium. Water freezes at 0° and boils at 100° . It has a bluish colour when seen in bulk and dissolves very many salts, and all gases to a greater or less extent.

85. White Vitriol.—Zinc sulphate occurs in zinc mines, where it is formed by the oxidation of blende. On the large scale it is obtained by roasting ores containing zinc sulphide, washing the mass with water and crystallising the solution. In the laboratory it is made by dissolving zinc, zinc carbonate or oxide in dilute sulphuric acid. It effloresces slightly in the air. It is used in medicine and in dyeing.

86. Zinc.—The ancients knew of the alloy of zinc and copper which we call brass, but it was a long time before the metal itself was known. It was in 1743 that the first works were established in England for the preparation of zinc on a large scale. The metal is prepared by heating its ores, the carbonate (or calamine) or zinc oxide, with coal. Zinc has a bluish-white colour: it melts at 433° and boils at 940° , and is 6.9 times as heavy as water. The metal is readily attacked by acids, and when

strongly heated in air burns, forming its oxide ; but it is not readily attacked by air when cold.

87. Zinc Oxide.—Occurs in nature as the mineral zincite and is prepared on a large scale by distilling zinc and collecting the ‘zinc white’ formed by the vapour burning in air. It is used as a paint. It is readily soluble in acids, forming the corresponding zinc salts.

EXTRACTS FROM A PAPER BY JOSEPH BLACK
ENTITLED ‘*Experiments upon Magnesia alba,
Quick-lime and other Alkaline Substances.*’
(Published 1755.)

BLACK had found that *magnesia* when strongly heated lost weight, lost moreover its power of effervescing when treated with acids, and he had found that the calcined or strongly heated *magnesia* became as heavy as ever when dissolved in acid and treated with such alkalis as washing soda, at the same time regaining the power of effervescing with acids. Black had found indeed, to use his own words, that ‘the crude *magnesia* seems to differ from the calcined chiefly by containing a considerable quantity of air, which air is unavoidably dissipated and lost during the dissolution.’

‘In reflecting afterwards upon these (and other) experiments, an explication of the nature of lime offered

itself, which seemed to account, in an easy manner, for most of the properties of that substance.'

'It is sufficiently clear, that the calcareous earths in their native state, and the alkalis and *magnesia* in their ordinary condition, contain a large quantity of fixed air; and this air certainly adheres to them with considerable force, since a strong fire is necessary to separate it from *magnesia*; and the strongest is not sufficient to expel it entirely from fixed alkalis, or take away their power of effervescing with acid salts.'

'These considerations led me to conclude, that the relation between fixed air and alkaline substances was somewhat similar to the relation between these and acids: that as the calcareous earths and alkalis attract acids strongly, and can be saturated with them, so they also attract fixed air, and are, in their ordinary state, saturated with it: and, when we mix an acid with an alkali, or with an absorbent earth, that the air is then set at liberty, and breaks out with violence; because the alkaline body attracts it more weakly than it does the acid, and because the acid and air cannot both be joined to the same body at the same time.'

'I also imagined, that when the calcareous earths are exposed to the action of a violent fire, and are thereby converted into quick-lime, they suffer no other change in their composition, than the loss of a small quantity of water, and of their fixed air. The remarkable acrimony which we perceive in them after this process, was not supposed to proceed from any

additional matter received from the fire, but seemed to be an essential property of the pure earth, depending upon an attraction for those several substances which it then became capable of corroding or dissolving; which attraction had been insensible as long as the air adhered to the earth, but discovered itself upon the separation.'

'Crude lime was therefore considered as a peculiar acrid earth, rendered mild by its union with fixed air; and quick-lime as the same earth, in which, by having separated the air, we discover that acrimony or attraction for water, for animal, vegetable, and for inflammable substances.'

'This account of lime and alkalis recommended itself by its simplicity, and by affording an easy solution of many phenomena; but appeared, upon a nearer view, to be attended with consequences that were so very new and extraordinary, as to render suspicious the principles from which they were drawn.'

'I resolved however to examine, in a particular manner, such of these consequences as were the most unavoidable, and found the greatest number of them might be reduced to the following propositions:

'I. If we only separate a quantity of air from lime and alkalis, when we render them caustic, they will be found to lose part of their weight in the operation, but will saturate the same quantity of acid as before, and the saturation will be performed without effervescence.'

'II. If quick-lime be no other than a calcareous

earth deprived of its air, and whose attraction for fixed air is stronger than that of the alkalis, it follows that, by adding to it a sufficient quantity of alkali saturated with air, the lime will recover the whole of its air, and be entirely restored to its original weight and condition.'

' III. We have shown, in the former experiments, that absorbent earths lose their air when they are joined to an acid ; but recover it, if separated again from that acid, by means of an ordinary alkali ; the air passing from the alkali to the earth, at the same time that the acid passes from the earth to the alkali.'

' If the caustic alkali, therefore, be destitute of air, it will separate a calcareous earth from acids, under the form of a calcareous earth destitute of air, but saturated with water, or under the form of slaked lime.'

The truth of these conclusions Black then established by experiment.

SOME DERIVATIONS

Acid, from the Latin *acidus*, sour.

Alkali, from the Arabic *al-qaliy*, calcined ashes (*qalay*, fry).

Azote, from the Greek *a*, not, and *zōō*, I live.

Carbon, from the Latin *carbonem* (acc. of *carbo*), charcoal.

Centigrade, from the Latin *centum*, a hundred, and *gradus*, a degree.

Chemistry, from alchemy, the art of turning baser metals into gold, or the Egyptian art, from the Arabic *al*, the, and *Khemia*, a Greek form of the native name of Egypt.

Chlorine, from the Greek *khlōros*, green : it is a green gas.

Copper, from the Greek *Kuprios*, of Cyprus, anciently renowned for its copper-mines.

Crystal, from the Greek *krystallos*, ice.

Deliquescence, from the Latin *de-*, away, and *liquescere*, to become wet.

Desiccator, from the Latin *de-*, away, and *siccus*, dry.

Effervescence, from the Latin *ef-*, out, and *fervescere*, to begin to boil.

Efflorescence, from the Latin *ef-*, forth, and *florere*, to blossom.

Hydrogen, from the Greek *hudor*, water, and *-genēs*, born.

Magnesium, from the Greek *Magnesios lithos*, the Stone of Magnesia, a country in Thessaly.

Malachite, from the Greek *malakhē*, a mallow : its colour resembles that of the mallow leaf.

Mercury, so named by the alchemists after the god Mercury.

Microscope, from the Greek *mikros*, little, and *skopein*, to see.

Nitrogen, from the Greek *nitron*, native soda, with which nitre was formerly confused, and *-genēs*, born.

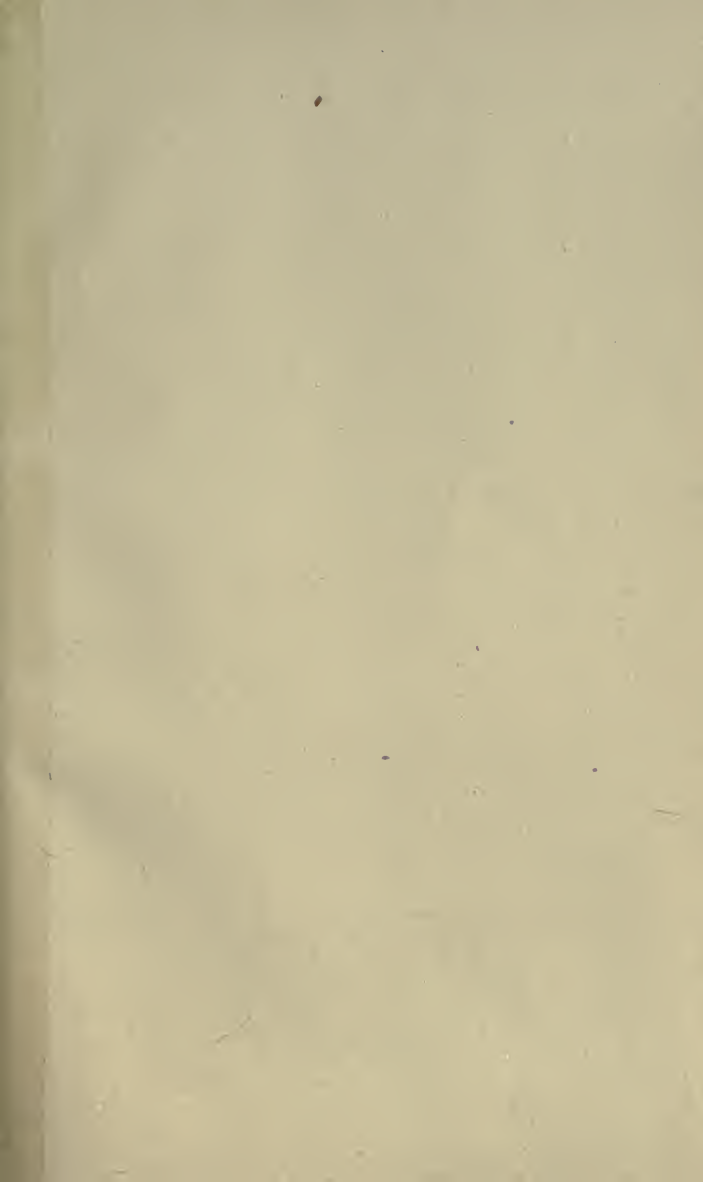
Oxygen, from the Greek *oxus*, sharp, and *-genēs*, born. At one time oxygen was thought to be present in all acids.

- Phenomenon**, from the Greek *phainomenon*, an appearance.
- Porcelain**, from a Portuguese word *porcellana*, a shell that resembles porcelain in appearance.
- Pyrites**, from the Greek *pur*, fire, and *-ites*, connected with. When struck sharply the mineral was known to give out sparks.
- Sal-ammoniac**, a salt that was said to have been made from camel's dung near the temple of Jupiter Ammon in the Libyan desert.
- Saltpetre**, from the Latin *sal-petræ*, rock salt, because it is sometimes found as an efflorescence on walls.
- Siderite**, from the Greek *sideros*, iron.
- Sublime**, from the Latin *sublimis*—perhaps *sub limen*, up to the lintel.
- Vitriol**, from the Latin *vitrum*, glass.

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